Temperature dependent formation of ion tracks in apatite and quartz studied using SAXS

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Ion tracks are narrow, cylindrical defects a few nanometres in diameter and up to tens of micrometres in length that result from the interaction of high-energy heavy ions with a target material. In nature, these tracks are produced by fission fragments from the decay of uranium in various minerals [1]. Quantitative and length analysis of these fission tracks provide information on the age and thermal history of geological material. Ion tracks also play an important role in high radiation reactor environments where they are formed at elevated temperatures.

We have previously shown that synchrotron-based small angle x-ray scattering (SAXS) is a powerful and non-destructive technique well suited for studying ion tracks with unprecedented precision [2]. SAXS can resolve small changes in the track radii that are challenging to resolve with conventional analytical techniques such as transmission electron microscopy. Thus SAXS is also an important tool in studying high temperature effects on ion track formation.

This work focuses on the effect of temperature on the size and morphology of ion tracks in apatite and natural quartz using SAXS at the SAXS/WAXS beamline at the Australian Synchrotron. The tracks were produced by irradiation with 2.2 GeV Au ions (GSI Helmholtz Centre) at temperatures between room temperature and 640°C. A linear increase in the track radius with temperature was observed [3]. In contrast, irradiation with low energy ions at elevated temperatures generally leads to lower defect concentrations due to increased thermally induced dynamic defect recovery. We were able to confirm the increase quantitatively by performing Molecular Dynamics (MD) simulations for quartz. The notion of increased track radii is particularly relevant for fission track dating in apatite, as natural occurring tracks can be formed at elevated temperatures in the earth crust. In addition, these findings are relevant when assessing the radiation resistance of nuclear materials that are often subjected to extreme conditions such as high temperatures and high-energy particles.

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